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INVESTIGATIONS OF IRRIGATION PRACTICE IN OREGON.

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INTRODUCTION.

Until within the last few years irrigation has played but a minor part in the agricultural development of Oregon, owing to the fact that stock raising has been the chief industry in the arid section, and irrigation has been considered as only an incident to this industry. These conditions are rapidly changing, however, and the irrigated farm is fast becoming a potent factor in eastern Oregon's development. The distribution of rainfall in the State and the regions in which irrigation is specially needed are shown in the following table, giving the average precipitation of different places in the State. In the first section is given the average annual precipitation at various points lying approximately in line east and west across the northern part of the State, the stations in the second section form a line through the central part of the State, and the stations in the third section are distributed along the southern boundary of the State.

Annual precipitation at various points in Oregon.

Place.	County.	Annual precipitation.
Northern part of State.		*Inches.*
Nehalem	Tillamook	114.56
Forest Grove	Washington	65.88
Portland	Multnomah	47.04
Cascade Locks	do	80.36
Hood River	Wasco	35.23
The Dalles	do	15.09
Arlington	Gilliam	9.11
Umatilla	Umatilla	8.84
Meacham	do	28.79
La Grand	Union	19.22
Joseph	Wallowa	17.64
Central part of State.		
Alpha	Lane	105.72
McKenzie Bridge	do	82.22
Bend	Crook	17.10
Prineville	do	8.74
Beulah	Malheur	10.10
Vale	do	10.71
Ontario	do	13.31
Southern part of State.		
Gold Beach	Curry	98.63
Grants Pass	Josephine	39.49
Jacksonville	Jackson	26.37
Ashland	do	25.11
Klamath Falls	Klamath	[a]25.00
Lake View	Lake	21.47

[a] Estimated.

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These tables show that along the coast the rainfall is very heavy, averaging approximately 100 inches annually. The average of 15 stations in the great valleys along the western slope of the Cascades is 40 to 60 inches. In the Umpqua and Rogue River valleys the rainfall is considerably less, and in these during a portion of the year it has been found profitable to resort to irrigation. East of the Cascade Range irrigation becomes an absolute necessity. In the Blue Mountains the precipitation averages 20 to 24 inches, but in all the surrounding region all intensive agriculture requires irrigation.

The greater part of the arable land of the State lies in the arid section, and can be brought under intensive cultivation only by irrigation. The extent to which this land may be reclaimed is, of course, dependent upon the water supply; but eastern Oregon is favored with a large supply of water, there being a number of large streams and a great number of smaller streams. The size of some of the larger streams is shown by the following table giving stream flow:

Discharge of some of the principal streams in eastern Oregon,[a] 1904.

Name of stream.	Place of measurement.	Date.	Discharge.			Total discharge during year.
			Maximum.	Minimum.	Mean.	
			Cubic feet per second.	*Cubic feet per second.*	*Cubic feet per second.*	*Acre-feet.*
Dorchester	Bend	December 21			2,412	
John Day	McDonalds [b]	October 26			580	
Do	do	December 26			570	
Umatilla	Umatilla	Year	8,031	9	964	697,200
Walla Walla	Milton	do	2,220	122	332	241,000
Grand Ronde	Elgin	do	8,349	44	1,168	842,200
Wallowa	Wallowa	do	2,300	172	653	474,200
Powder	Baker City	do	1,592	2	204	147,800
Malheur	Vale	do	14,540	40	1,304	937,400

[a] U. S. Geological Survey, Report 1905.
[b] Point of measurement, 16 miles above mouth of river.

On most of these streams water is already being used for irrigation, and from some the entire low-water flow is being diverted during the summer months, but as yet practically no steps have been taken to conserve the winter floods and the water that is diverted is rarely used economically, so that there is a large supply for future development.

The climate of the northern part of eastern Oregon is much milder than that of the more elevated region in the southeastern part of the State, and it is in the northeastern section that the greatest development under irrigation is to be expected. In this section the elevation of the agricultural land does not exceed 4,000 feet, and the greater part lies below 3,000 feet, while the region directly south of the Columbia is for the most part less than 1,000 feet above the sea. In the central and southeastern parts of the State, while the elevation is not much above 4,000 feet, the climatic conditions are such that only

the hardier crops can be raised successfully. Along the Columbia River the growing season is at least six months in length, and it is possible to raise all crops and fruits of the Temperate Zone. In the Blue Mountain region and in the valleys lying along the eastern border of the State, conditions are somewhat similar to the Columbia River section, and where the elevation is not too great similar results are accomplished. All through the eastern part of the State there is practically no rainfall during the growing season, making it possible to mature the crops with the greatest success and to harvest them without damage. The rainfall during the winter and spring months varies from 7 to 20 inches, depending upon the location, but this comes at such a time that it can be used only in a limited way for irrigation.

The soils in those sections of Oregon which are now open to settlers are for the most part of volcanic origin. On the bench lands the soil is light and fine textured and, as a rule, is devoid of brush. In the valleys and along the streams are rich deposits of alluvial soil which, although of the same general character as the highlands, are much darker in color by reason of organic matter which they contain, and on this land there is usually a growth of sagebrush.

INVESTIGATIONS UNDERTAKEN.

Realizing the importance of irrigation to eastern Oregon, the governor of the State, Hon. George E. Chamberlain, requested this Department in the spring of 1905 to undertake an investigation of irrigation conditions in that section. Work was started in three of the irrigated sections of the State, and other irrigated sections were visited and plans outlined for investigations in the future.

The work of the season comprehended studies of the methods of preparing land for irrigation and applying water: Loss by seepage from canals, the duty of water, and winter irrigation and methods of conserving soil moisture. In Klamath County, in southeastern Oregon, the work was carried on by Mr. F. L. Kent, of the Oregon Agricultural Experiment Station, under a cooperative arrangement between this Department and the State experiment station. In Crook County the work was done on an experimental farm near Bend, Mr. Elias Nelson, who was in charge of the farm, having immediate supervision of the experiments. In the northeastern part of the State the investigations were carried on by the writer, who also had general supervision of the work in the other sections of the State.

This circular contains the reports of the work done, except that on duty of water. In the discussion it has been deemed advisable to include a rather detailed description of the best methods of preparing land and applying water, since the practice in Oregon is yet to be greatly improved, and description of methods now employed would be of little value to new settlers.

PREPARING LAND FOR IRRIGATION.

The first question that confronts the settler on a piece of raw land is, How can he best reduce that land to a state of cultivation? In preparing the description of the methods of preparing land for irrigation the needs of such settlers have been kept constantly in mind.

REMOVING NATIVE VEGETATION.

Sagebrush is about the only native vegetation which needs to be removed in preparing land for irrigation. This is usually shallow-rooted, and when so can be thrown out with the plow when the land is broken. If too large and deep-rooted to be removed in this way it may be broken down by dragging a railroad rail across the land in both directions, which will break down and pull out so much of the brush that the remainder can be turned out with a plow. If the growth of brush is very heavy perhaps the best way of clearing is to grub by hand. After the brush has been turned out of the ground it can be raked in windrows with an ordinary hayrake or bunched during the process of harrowing, after which it is burned or stacked for fuel.

LEVELING.

The leveling of the land after it is cleared is a phase of preparation which in the past has been too often overlooked. The result is that fields are uneven, water is distributed over them with difficulty, and there are portions that do not receive their full share of water. With a poor distribution of water the crop also is uneven. To avoid this the knolls and soil heaps that have collected around clumps of brush must be dragged down and scraped into depressions, and sand heaps blown up by the wind must be reduced. The best results in this work are obtained with the wheel or drag scrapers. These are especially adapted to the work where the earth has to be moved a considerable distance. For short hauls and for general leveling the buck scraper of the design shown in figure 1 is a very efficient implement. When the board is 24 feet long six horses are required for its operation.

The cost of leveling land and preparing it for irrigation will be found to vary from $2.50 to as high as $35 per acre. Within the past year considerable land in the Umatilla Basin has been leveled and prepared for check irrigation by Mr. H. G. Newport. His estimate of the cost per acre varies from $25 to $30.

Over the northern part of the State and especially along the Columbia River there are heavy prevailing winds from the west which, especially in the light sandy soils, do much damage. Unless care is exercised the settler is very apt to have a sand blow started on his land, which, before it can be stopped, will do immense damage not only to

his own land but to neighboring tracts. In many cases this damage by the wind has been successfully prevented by breaking the land in strips 2 to 3 rods wide, leaving unbroken strips of the same width. The strips should run north and south, or at right angles to the prevailing direction of the wind. Where this practice is followed the sagebrush or other native growth is put in windrows on the windward side of each plowed strip, making something of a wind-break. If water is available it may be possible to break up the whole tract at once, using the water to prevent the starting of sand blows. Under irrigation most any grain crop will do for the first season. Without irrigation rye has been found to be the best crop. If rye is planted the first year on the broken strips, and cut so as to leave a high stubble, the unbroken strips may be broken during the second year as the newly plowed strips will be protected by the rye stubble. After one or two crops have been raised on this sandy soil there is little danger of its blowing, and under irrigation some such crop as alfalfa will

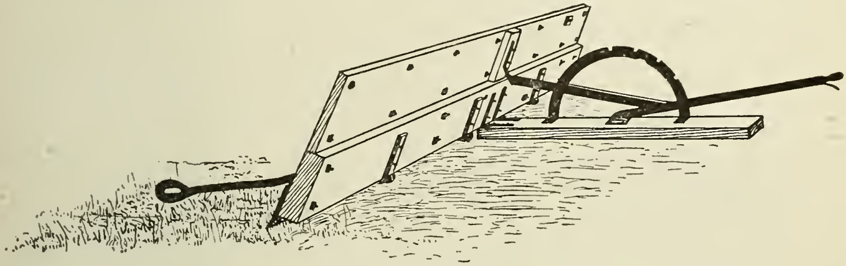

FIG. 1.—Buck scraper.

have been planted, which will prevent any damage being done by the wind.

In sections where fruit is grown it is necessary to provide protection against these winds, otherwise both the crop and the trees are seriously damaged. Wind-breaks are best formed of shade trees of rapid growth planted closely together and allowed to sprout close to the ground.

METHODS OF APPLYING WATER.

Three general methods of applying water to field crops have been developed in the irrigation practice of the arid region. Each one of the three methods has its own field of usefulness, and under the right conditions will prove more satisfactory than either of the others. Not until conditions are thoroughly understood should the farmer decide finally on a method.

FLOODING FROM FIELD LATERALS.

This system of irrigation is the one commonly employed in the States of Utah, Colorado, Montana, and Idaho. It is especially well adapted to soils which do not wash easily and will not bake. The

usual practice is to convey the water along one, and sometimes two, sides of the field in permanent laterals from which at intervals of 50 to 150 feet water is taken into laterals which traverse the field. These should have a grade of 1 to 3 inches per rod, depending upon the texture of the soil. At intervals of 1 to 3 rods water is taken from the field laterals through cuts in the banks and flooded over the field. When one portion is thoroughly soaked the lateral bank is cut at another point. If the stream be large enough, two, three, or more openings in the field lateral may be kept running at a time.

In this way one man should irrigate 3 to 5 acres a day. To accomplish the most work he should have a stream of 2 to 4 cubic feet per second, depending upon the nature of the soil, the general slope of the surface, the stage of the crop, and the methods employed in controlling the water at points where it is turned out of the head laterals and out of the field laterals.

In cases where the extra expense is warranted, small wooden head gates may be used in diverting the flow from the head lateral. Quite as good results can be secured, however, by the use of the canvas dam, which also can be used for turning water from field laterals. This dam consists of a large piece of canvas 6 to 10 feet square, one edge of which is fastened to a pole or iron rod sufficiently long to reach across the lateral and strong enough to support the canvas against the pressure of the water. Being light, the dam can be carried from one part of the field to another. It is inexpensive, and is made often of scrap material. An old wagon sheet or the carrier apron of an old binder or header will do for the canvas sheet and any strip of tough wood will do for the crosspiece. Under certain conditions a wrought-iron rod is preferable to the wooden crosspiece, for if it is desired to turn out only a portion of the stream, the rod may be bent downward and the remainder of the stream allowed to flow on.

In Montana the following method is used in irrigating grain from field laterals. When the grain is 3 or 4 inches high the field laterals 60 to 150 feet apart are plowed out and dams are made in the laterals every rod or two by means of the homemade dammer, which is a small scraper drawn by one horse. This collects the loose dirt in the ditch bottom and the driver dumps the dirt at the points desired. The stream is turned into the head of the lateral and the water flows to the first dam, where it is forced out of the channel and spreads over the surface of the field. When the soil in the vicinity of the first dam has been saturated the dam is shoveled out and the water allowed to flow on to the next dam. In fields of alfalfa and clover better results are obtained with straw manure dams, the manure being hauled onto the field in the spring and deposited in small piles along the field laterals.

The advantages and disadvantages of the flooding method may be summed up as follows: The principal advantages are: The cost of

preparing land is comparatively small; aside from the general turning up of the field's surface, there is no need of disturbing the surface soil; it readily adapts itself to the delivery of water in continuous flow. The principal disadvantages are: The amount of labor required to handle the water is large; one man can not thoroughly irrigate on an average more than 3 acres in 10 hours; in all grain crops the field ditches have to be renewed each spring; it may be difficult to distribute the water evenly over the surface.

IRRIGATION FROM SMALL FURROWS.

This system of applying water is especially adapted to compact, clayey soils. Such soils are apt to bake when wet, and the only way in which this may be averted is to apply the water in such a way that the surface is not wet. In laying out a system of small furrows the field is brought to a comparatively uniform slope, and after the crop is seeded small furrows 2 to 4 inches deep are run in the direction of the slope at intervals of 20 to 45 inches. These small furrows are supplied from a head ditch across one border of the field. Water is admitted to each furrow through a small spout, usually made of ordinary lath. These spouts extend through the ditch bank and allow small streams to enter the heads of the furrows, a number of streams being kept running at the same time. From one irrigating stream of 2 cubic feet per second, perhaps 30 to 40 furrows will be supplied. From the small furrows the water soaks away on either side until the strips of soil between are sufficiently wet. In this way water is supplied to the roots of the crop without the surface becoming saturated, and all danger of baking is averted.

This method is of value also in handling a small stream of water on land in which water spreads well. A small stream of water may be set and left without further attention until the space between furrows becomes thoroughly soaked. When the furrows in a field become set little attention is required to obtain the proper distribution of the water. The distance between furrows depends on the ease with which the water saturates the soil. This will be found to vary quite widely. The rapidity of percolation also gives a key to the best length of furrows. With furrows of too great a length the soil next to the head ditch will become too wet before the soil at the lower end has received sufficient water. In general terms furrows should be not longer than 15 or 20 rods.

The advantages of this method are: The surface soil is not so apt to bake; a small head of water may be economically handled; there is less loss of water by evaporation than with flooding. The principal disadvantages are: The difficulty of maintaining an equal flow in all furrows; where the soil is not uniform in texture an even distribution is hard to secure; the upper end of the field is likely to receive more

water than it requires; the furrows interfere with cutting and hauling the crop.

A modification of the small-furrow method has been used in irrigating grain in Utah. The planted area is gone over with what is called a "marker," which consists usually of an 8-inch log, 8 or 10 feet long, to which is attached a tongue and doubletrees. Wooden blades or teeth 2 to 3 inches wide and 12 to 16 inches long are inserted in the log and the whole forms a comb-like implement which makes the furrows 2 or 3 inches deep. The usual spacing of the teeth in the log is 18 to 24 inches.

Many mark the fields after sowing, while others wait until the grain is up. At intervals of 2 to 3 rods water is turned from the laterals onto the fields and directed into the small channels made by the marker. However, the water is not confined to the furrows, but is allowed to overflow them. The furrows serve only as guides to carry the water to all parts of the field, thus insuring an even distribution. Where the small furrows are made across the slope they aid in distributing the water transversely and a larger stream may be taken from the main lateral. Where the marks run with the slope more attention is required to prevent them washing into large channels and becoming collectors rather than distributers of the water. In some instances the marker is run in such a direction as to place the channels on a slight grade. This method gives perhaps the best results. During the first irrigation close attention must be given to the distribution, and earth must be put here and there in the small channels to make sure that the water spreads evenly. Each time the field is irrigated the small channels become more fixed, and toward the end of the season but little attention is required to thoroughly irrigate the tract.

The main distributing laterals in the field should be placed 10 to 20 rods apart, depending upon the slope of the land and the nature of the soil, and may be given grades of one-half inch to an inch per rod. Each lateral should carry 2 to 3 cubic feet of water per second, as one man can usually handle this volume with ease after getting the stream set.

CHECK IRRIGATION.

This method of irrigating has been developed most highly in California. As conditions in Oregon are very similar and as check irrigation is already becoming popular in certain sections it has been thought best to include a rather full description of this method.

There are two systems of check irrigation: (1) The contour system, in which all levees are on contour lines, dividing the field into checks of varying sizes and irregular shapes; and (2) the rectangular system, in which all levees are located on straight lines. If the tract contains depressions, other things being equal, contour checks will be less ex-

pensive, since they can be so located as to require a minimum amount of labor in their construction and in the leveling of the bottoms of the checks. Building levees on straight lines necessitates the moving of much more earth to form the levees and brings the bed of each check to a level. Where the slope of the tract is quite uniform in each direction and the surface is unbroken rectangular checks are better, since they conform nicely to culture areas and to property lines and add to the ease with which fields can be cultivated.

If alfalfa or grain is to be raised it may not pay to go to the expense of building rectangular checks, but if fruit trees, vines, or furrow crops are to occupy the land the expense of providing large rectangular checks will be more than repaid by the future ease in irrigation and cultivation.

LAYING OUT CHECKS.

With either kind of checks the nature and amount of slope of the land govern the location of levees and sizes of checks. On all land which has a slope of 4 to 10 feet per mile contours must be located with an instrument. The expense of this will, of course, vary with the roughness of the land to be checked, but a good man, with his instrument and one assistant, will outline checks on 25 to 35 acres in a day, making the cost 20 to 30 cents per acre. It would probably be more expensive than this for the farmer to do the surveying himself and, being unfamiliar with this kind of work, the chances are he would not make the best choice of location for levees and laterals and would cause himself no end of trouble in constructing and maintaining his checks. However, for those who undertake the work without the help of a surveyor, the following suggestions are made:

After having determined the slope of the land, the next step is to fix the approximate size of the checks by the difference in elevation between checks. The best results are obtained where the vertical difference between checks is 4 to 10 inches. If greater than this the levees are apt to give way under the pressure of the water, and when this happens the heavy fall to the next check causes a bad washout. Where the slope of the land is so great as to require a larger difference than 1 foot in order that the levees may not be less than 50 feet apart, the check system should not be used. Observations in San Joaquin Valley, California, suggest 0.75 to 1.5 acres as the best size for checks. On a tract having a uniform slope the difference in level between the tiers of checks would be constant, and all levees would be approximately the same distance apart.

When the survey of a contour check system is being made usually no stakes are set, but the location of each levee is marked by a shallow plow furrow, the course of which is indicated by the surveyor walking directly ahead of the plow. In laying out rectangular checks the

corners of checks are indicated by stakes, from which the levees are constructed. As a guide for bringing the bed of each check to a level, a few random stakes are set between the levee furrows, all in any check having their tops on the same level.

CONSTRUCTING LEVEES AND LEVELING CHECKS.

Building levees and leveling checks is work that the farmer can do himself. Land which is to be checked is usually sown to grain or summer fallowed the previous year in order that the soil may be in good condition to be handled with a scraper. Various implements are used in this work, but of all perhaps the best results are secured with wheel and drag scrapers, especially where there is a long haul. For short hauls and for smoothing and leveling checks the ordinary buck scraper does rapid work. (See fig. 1, p. 5.)

Construction of levees and leveling of adjacent checks can be carried on at the same time, the earth being dragged from the highest points of the checks to the nearest low places in the levees. When the levee surrounding any check has been built the check inclosed, if the scraping has been well done, will be nearly level. On new soil which has never been saturated it is not necessary to complete the leveling before the first application of water, for the reason that all land settles more or less after first being saturated, and the final leveling should be left until after this settling has occurred. With level checks only a small depth of water is brought to bear on the levees, and the danger of breaks and washouts is lessened.

The difference in elevation between adjacent checks will determine the height of the levees. The crest of the levee separating two checks should stand 8 or 10 inches above the level of the higher check. Its top width should be not less than 2 feet, and its bottom width, say for a 1-foot levee, should be at least 15 feet. In some checking already done in Oregon the levees have been given a narrow base and steep-sloping sides. No implement can be taken over without danger of damaging the levees as well as the implement, and no crop will grow on such a levee. The chances of the levees breaking under water pressure are also increased by their diminished cross section. Levees built broad and low form no obstruction in the field; they are more lasting, and owing to their flat slope the crop grown, if it be like alfalfa, will entirely cover the levees, and the whole area of the field is made productive.

DISTRIBUTING LATERALS FOR CHECK IRRIGATION.

The location of laterals will be governed by the character of the soil and the slope of the ground. On light soils a grade of 2 or 3 feet per mile should be the maximum. In general, the best results

will be obtained if each check is supplied directly from a lateral, the lateral being made to form a portion of its boundary. In most cases such an arrangement is possible, and where the expense is not prohibitive this plan should be adopted. In cases where it is necessary to supply one check through another a broad, shallow depression across the check through which the water is to be carried will confine the flow of the stream and lead it to the check to be watered, without its spreading over the bottom of the higher check. If this depression be made 10 or 12 feet wide and 4 to 8 inches deep and given just enough slope to drain nicely toward the lower check gate, the crop will cover the sides and bottom of the channel and all implements will cross it without inconvenience.

In the construction of laterals the scraper is worked at right angles to the line of the lateral. The earth to form the banks is taken from the bottom of the channel and from the high parts of adjacent checks.

SETTING CHECK BOXES.

Various forms of boxes are used to control the flow of water from the laterals, the size depending on the amount of water to be controlled. Serviceable boxes can be made of 1-inch or 1½-inch lumber, with 2 by 4 framing timbers. If made of Oregon fir, such boxes should last several years. Whatever the style of box used, it should be set in the banks of the lateral, so as to withstand the greatest pressure that will be brought to bear upon it. Flashboards should be made of 2-inch lumber, preferably 6 inches wide. Boards of this thickness will not warp when left in the sun. In setting boxes, the floor should be placed 10 or 12 inches below the level of the check to lessen the liability of the water washing under the boxes. For average land good check boxes can be provided for $1 to $5 per acre.

COST OF CHECKING.

No exact estimate can be given of the expense of checking, as the price will vary with the character of the land and also with the locality. For contour checks in California the cost of building levees, leveling the checks, and constructing laterals averages about $7 or $8 per acre on ordinary land, including surveying at 20 to 30 cents per acre. Check boxes at $1 to $5 per acre would bring the total expense up to $8 to $13 per acre. In building rectangular checks on uniformly sloping land, one man with four horses and a scraper can check and level at the rate of 1 acre in two to two and one-half days. If the land be quite smooth one man can do this work at the rate of 1 acre a day. This would include the construction of laterals. In Oregon the cost of checking has been found to vary from $15 to $30 per acre for ordinary land.

COST OF IRRIGATION BY DIFFERENT METHODS.

While the conditions in Oregon are quite variable, yet taking the irrigated portion as a whole the average cost of preparing land and irrigating will not be far from the general average of the other arid States. In a bulletin published by this Office [a] figures relative to the cost of preparing and irrigating land in the various leading irrigation States have been given. In the belief that this data will prove of much value to Oregon irrigators the summaries of costs appearing in that bulletin are here reproduced. The extreme variation in the different sections was great, and in the summaries it seemed best to give only the average maximum and minimum cost per acre.

Summary of cost of irrigating for a period of five years.

Period.	Requirements.	Average minimum cost per acre.	Average maximum cost per acre.
Flooding.			
First year	Grading the surface and building field ditches.	$2.00	$5.00
	Irrigating three times	1.00	2.75
Second year	Repairing or making ditches and irrigating	1.20	3.00
Third year	do	1.20	3.00
Fourth year	do	1.20	3.00
Fifth year	do	1.20	3.00
Average yearly cost		1.56	3.95
Furrow irrigation.			
First year	Building checks and laterals	1.00	10.00
	Irrigating three times	1.50	2.25
Second year	Making furrows and irrigating	2.00	2.75
Third year	do	2.00	2.75
Fourth year	do	2.00	2.75
Fifth year	do	2.00	2.75
Average yearly cost		2.10	4.65
Check method.			
First year	Building checks and laterals	8.00	16.00
	Irrigating three times	.50	1.50
Second year	Repairing laterals and irrigating	.75	1.75
Third year	do	.75	1.75
Fourth year	do	.75	1.75
Fifth year	do	.75	1.75
Average yearly cost		2.30	4.90

FLOOD-WATER IRRIGATION.

The streams of eastern Oregon with few exceptions discharge the greater part of their flow during the nonirrigating season, leaving probably not to exceed 25 per cent of their annual discharge for direct diversion during the irrigation season. The greater part of the discharge occurs during the late winter and early spring months, say during January, February, March, and April. On many of the streams storage reservoirs, except in a limited way, are out of the

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 145.

question by reason of there being only limited reservoir sites. On the Umatilla River, for illustration, there are no large natural reservoir sites, such as would be required to store the 80 per cent[a] of the stream's yearly discharge that occurs during the period from November 1 to May 1, and such reservoirs as might be provided could at the best take care of only a part of the flood water. On such streams as the Umatilla, therefore, there is a need of utilizing this flood flow in some other manner; and as it can not be held back for use during the summer months the water must be applied to the land during the winter and spring months and stored in the soil, where it can be drawn upon by the plant during its period of growth.

For a good many years this method of utilizing flood water has been practiced to a limited extent in the Umatilla Basin in the Butter Creek bottoms. Butter Creek is a torrential stream, and practically its entire discharge occurs during the late winter and early spring months. Along the creek for a distance of some 6 miles above its mouth the bottoms widen out and form an area of 5,000 or 6,000 acres, which is easily irrigated from the creek. These lands are irrigated during the winter and early spring when the crops are dormant. This practice has proved very successful, and has led to its adoption on all the bottom lands that the creek will supply. During this period water enough to cover the land to a depth of 5 to 8 feet is applied, and the soil down to the impervious stratum is completely saturated. In this way sufficient water is stored in the soil to satisfy the needs of the plants during the dry summer season.

The soil of the creek bottoms is an alluvial deposit of volcanic ash, which varies in depth from 8 to 30 feet, and from all indications is underlaid by undulating strata of impervious cement gravel. These strata, as indicated by their appearance along the creek bank and in wells, seem to lie in successive layers, the general slope of which is either less than the general slope of the creek bottom or else they slope in a direction opposite to the slope of the creek. The result is that they form a water-tight bottom to the valley, making a large underground reservoir composed of basins of varying sizes which retain in the soil the water applied in the spring.

Water is taken from the creek in small ditches which carry the water to the highest borders of the fields, and from there is carried by smaller laterals to all parts of the fields and spread over the surface. Little care is exercised as to economical distribution, the sole idea being to apply as much water as the soil will absorb.

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[a] The reports of the U. S. Geological Survey show that during 1904 the Umatilla River discharged 693,588 acre-feet of water at its mouth. During the six months from May to November the volume discharged amounted to only 127,104 acre-feet, or a little less than 20 per cent of the total yearly discharge.

The principal industry is stock raising, and the principal crop is alfalfa, which is used as winter feed and for finishing stock for market. The yield with this one irrigation is usually three cuttings, estimated variously at 5 to 7 tons per acre, and as the crop is usually removed by the 1st or middle of August, good pasturage for a period of five to eight weeks is provided. In addition to the alfalfa there are several orchards along the creek which produce good crops of apples, peaches, apricots, pears, and prunes, but the growing of fruit has been little more than an incident to the production of alfalfa. The success attained in fruit raising in this section attests, nevertheless, the value and reliability of winter irrigation under proper conditions.

A concrete example of the results of flood-water irrigation may be cited in the home ranch of Mr. O. F. Thompson, which has an area of 350 acres. One field of alfalfa was seeded twenty-five years ago, and to-day, although too old to be in the best bearing, it yields a good crop of hay in favorable years. Some of the apple trees were planted in 1861 and are still in a thrifty, healthy condition.

The alfalfa is usually irrigated in February or March, or sometimes as late as April. The orchard is irrigated as late as possible, usually March or April. The ordinary methods of irrigation are employed, except that much more water is applied to the land than would be put on in an ordinary summer irrigation. Water is kept flowing onto the land for a period of eight to ten days, or until the soil will absorb no more. No measurements have ever been made, but as nearly as can be estimated it is probable that the land receives water to a depth of 5 to 8 feet. In the alfalfa fields no effort is made to conserve the soil moisture other than to allow the plants to shade the soil surface as much as possible. In the orchards thorough cultivation is practiced, and a heavy dust blanket, free from weeds, is maintained throughout the season.

In average years the alfalfa yields two good crops and pasturage for two to four months. The yield of hay for the two crops will average 5 to 7 tons per acre, which, at current prices, means a return of $30 to $40 per acre. The pasturage is worth $1.50 per acre. The cost of producing and disposing of the crop may be summed up as follows:

Cost of raising alfalfa.

Irrigation, per ton	$0.05
Cutting and stacking hay, per ton	.65
Feeding, per ton	1.00
Total	1.70

Assuming the yield of 1 acre to average 6 tons, the gross return at current prices is $36. The cost of producing and feeding the hay

may be approximated at \$2 per ton or \$12 per acre. This gives a net return per acre of \$24.

The success which has been attained in the use of flood water on Butter Creek has led to the belief that similar results may be secured upon much of the plateau land which is so situated as to be easily covered by water diverted directly from the streams and which would be readily brought under cultivation. The plateau soils are very similar to those along Butter Creek and are equally as susceptible of cultivation. The water supply during the winter and spring is abundant, and at first thought it would seem that these lands can be brought under cultivation quite as successfully as have been those on Butter Creek. It seems, however, that the peculiar underlying formation of the Butter Creek bottoms is responsible more than any other factor for the great success that has been attained, and this success should not be given too much weight in sections which have not impervious subsoils.

On plateau lands, where the water table may be brought within 10 or 15 feet of the surface, it may be reasonable to expect that great success with flood-water irrigation will be attained. Where, however, the conditions are such that the water is held in the soil by capillarity only, the success will be less sure. To replace the moisture lost by evaporation from the surface and that used by plants, it is necessary that there be a supply of free water which can be drawn upon by capillarity, else the upward motion of the soil water becomes slower and slower, and finally the amount of water available for plants becomes reduced to such an extent that the plant can no longer thrive. If the soil be fine, much water will be held within the pore spaces; if it be coarse and sandy, the greater part will drain away. Under these circumstances a thorough investigation of the soil and subsoil conditions will be necessary in determining the probable value of flood-water irrigation as an investment.

In the Umatilla Basin at the present time two or three canals are being constructed which will supply flood water only. With the completion of these the practicability of winter irrigation will receive its first thorough test on lands in this section which do not present exceptional advantages.

What has been said thus far deals only with the benefits of flood-water irrigation. On the other side the evils are equally important. All arid soils are more or less impregnated with alkaline salts, and where there is not good drainage they are likely to be brought to the surface by the use of large quantities of water. Unfortunately, winter irrigation requires just such conditions. The low-lying lands in hollows and swales are the most apt to be injured, for this land must receive the drainage from the higher lands and water logging will result. Artificial drainage would seem to be the only relief for such

a condition. If artificial drainage can be profitably undertaken—if the productiveness of the lands warrants the expense—the low lands which would otherwise become worthless may be saved from injury; if not, there seems nothing to be done except to abandon the low land for the higher land.

SEEPAGE LOSSES FROM CANALS.

The loss of water from canals by percolation is of vital importance to the irrigators of Oregon. In sections where water is scarce the saving of water is important, and in other sections where the water supply is plentiful the saving of water is not so important as preventing the swamping of low lands. It is necessary, therefore, that attention be paid to this matter, whether the water supply is abundant or scarce. In this matter the Oregon irrigator has this great advantage—his irrigation is comparatively recent, and by taking at once steps to check seepage losses he can prevent the great damage to lands which has resulted in other places.

In the past season the investigations were for the most part a determination of the amount of loss and its location. Under only one canal was a study made of the methods of prevention. This was on the canal of the Oregon Land and Water Company in Umatilla County. The method of determining the loss from a canal consists in measuring the amount of water entering the upper end of a section, the outflow through laterals, and the outflow at the lower end of a section. The difference between the outflow and the inflow is the loss. The shortest length of section in which the loss can be determined with any reasonable degree of accuracy is approximately 1 mile for medium sized ditches. If the length be shorter than this, the loss may be so small as to be less than the error in measurement due to the use of the current meter. With an ordinary current meter it is possible to measure within about 2 per cent of accuracy. If then the loss be less than 2 per cent the results might show a gain as easily as a loss in flow.

IRRIGATION CANALS FROM DESCHUTES RIVER.

An irrigation company has constructed two large canals for the irrigation of lands in Crook County. The water is taken from the Deschutes River about 2 miles above the town of Bend. From there the water is conveyed in flumes and earthen channels to a point some 2 miles below the head gate where the canal divides, one branch line following a low level and the other maintaining its grade and supplying the high lands. The canal was constructed in 1904. The high level had been in use but six months at the time the measurements were made. The material through which both the canals run is

volcanic ash. At intervals along the line it has been necessary to make thorough cuts through lava dikes, and in many places sheet lava has been encountered at a short distance below the surface. Construction under these conditions has been difficult, and many of the fixed rules regarding construction of earthen channels have necessarily been abandoned. For instance, it has been found expedient, by reason of having considerable fall, to carry the grade line as near the surface of the ground as possible and to make use of all the natural ravines in order to cheapen construction. If a uniform grade had been maintained difficulty would have at once been encountered with the sheet lava. Where it was possible the bottom of the canal was kept above this sheet and the channel confined on either side by embankments. Where, however, it was impossible to maintain the channel in this way thorough cuts were made. From the nature of the soil and of the lava-rock formation through which the line passes, it is only reasonable to expect that much water will be lost by percolation or by direct leakage from the channel. It is not to be expected that the measurements that have been made in 1905 will be of much value because the channel will naturally improve rapidly, and the losses in subsequent years will naturally be less than while the canals are new. In order, however, to have a record of the loss from these canals while they were new, it was thought best to make seepage measurements on them and thereby begin a series which should be continued in subsequent years.

PILOT BUTTE CANAL.

The measurements on the Pilot Butte canal were begun at Station 75, where a 15-foot rectangular weir is located. At all other stations the measurements were made with the current meter. On September 5 the losses in the first 4 miles of the line were determined, the discharge at the head on this date being 88.8 cubic feet per second. The remaining sections of the line were measured on September 8, with a discharge of only about one-half that in the canal when the two upper sections were measured. The results, therefore, of the entire line can hardly be compared, since the loss will vary considerably with the amount of water being carried.

The results of the seepage measurements on the Pilot Butte canal have been brought together in the following table, in which are given the discharge at the ends of the various sections, the amount of water being diverted from each section in laterals, and the loss in cubic feet per second in each section. In the last column is given the percentage of loss per mile. This figure is useful in making

comparison between different canals of approximately the same size and is therefore inserted:

Seepage losses, Pilot Butte canal, September 5 and 8, 1905.

[In cubic feet per second.]

Section.	Character of channel.	Length of section.	Discharge, upper station.	Diversions.	Discharge, lower station.	Loss in section.	Loss per mile.	Percentage of loss per mile.
Stations.		*Miles.*						*P. ct.*
75+100 to 184+50	Extremely rough, heavy grade; numerous natural drops.	2.07	88.8	1.00	78.4	9.4	4.5	5.1
184+50 to 281+40	Same as section 1	1.84	78.4	8.0	63.8	6.6	3.6	4.6
71+00 to 228+90	Rough in places; natural channels used in places; some silting where grade is light. Water surface, 24 feet wide; depth, 1.3 feet.	3.00	37.8	2.2	30.4	5.2	1.7	4.6
228+90 to 322+90	Much the same as sections 1 and 2; toward lower end grade is light, and some silting. Water surface, 32 feet wide; depth, 1.15 feet.	1.78	30.4	0	28.8	1.6	.9	3.0
322+90 to 630+00	Big rock cut, below which grade is heavy for one-third length of section, below which grade is light. Water surface, 36 feet wide; depth, 1.15 feet.	5.81	28.8	0	26.4	2.5	.4	1.4
630+00 to 760+00	Grade light; channel entirely in cut. Water surface, 19 feet wide; depth, 0.9 foot.	2.25	26.4	7.9	22.2	4.1	1.8	6.82
Total		16.75				29.4	1.75	

OREGON CENTRAL CANAL.

The measurements on the Oregon Central canal were begun at station 34+75. The flow in the canal had been increased at 4 o'clock that morning to 56.6 cubic feet per second, but this flow had become steady by 10 o'clock, when the measurements were begun. It was intended that the head should be much larger than this, so that a part of the flow would carry to the end of the line where construction work was being carried on, but the head turned in was not sufficient to reach the full length, and as a result the measurements on the first two sections only, covering a distance of about 5 miles, were considered of value. Beyond this the stream was so small that it would have been useless to have carried the measurements farther. For this reason the loss which the measurements show may be taken as being excessive, for not only is this channel a new one, but also it had been comparatively dry for some time and would absorb much more water than it would if the water had been running continuously.

Section No. 1 extended from station 34+75 to station 170+50, 2.5 miles. The channel is in rock cut for the first 2 miles. The remainder is in earth with small rock cuts at intervals. Throughout the

section the canal is held to grade, the grade varying from 0.5 to 0.7 foot per 1,000. The bottom of the channel is well silted, but the banks are in approximately the same condition as when built, no large head of water having been carried in this ditch. The width of the canal at the point where first measured was 33 feet and the maximum depth 1.35 feet. At the lower end of the section the width of the water surface was 39.5 feet and the maximum depth 1.22 feet.

Section 2, extending from station 170+50 to station 285+50, 2.18 miles, is also carried on a variable grade, and aside from being a new channel is in good condition. The width of the water surface at the lower end of this section was 53 feet and the greatest depth of water at the point of measurement was 1.3 feet. At the lower end of the section the water was backed up for a considerable distance and the channel was well silted and in good condition. The results of the measurements on these two sections of the Oregon Central canal are brought together in the following table:

Seepage measurements, Oregon Central canal, September 6, 1905.

[In cubic feet per second.]

Number of section.	Section.	Length of section in miles.	Discharge upper station.	Diversions.	Discharge lower station.	Loss in section.	Loss per mile.	Percentage of loss per mile.
	Stations.							
1	34+75 to 170+50	2.51	56.6	0	38.9	17.7	7.1	12.5
2	170+50 to 285+50	2.18	38.9	0	23.0	15.9	7.3	18.27

When water was first turned into this line, considerable difficulty was experienced in preventing excessive leakage through crevices in the bottom of the channel, especially in the rock cuts. It seemed as though the water would percolate through the thin layer of sheet lava which underlaid the channel and would gradually displace the sand which supported this layer, and large sections of the lava sheet would cave in and form immense crevices in the bottom of the canal into which the water would pour continuously, evidently finding its way into some subterranean gallery from which it in all probability found its way back to the river. After shutting the water out of the canal these holes were filled with bowlders, then fine sagebrush, manure, and soil were all tamped in a firm mass and puddled with water. This treatment seemed to be quite effective and prevented much of the leakage which had occurred at these points. The measurements seemed to show, however, that the channel is still very porous and that a great amount of water finds its way into the porous lava formation below. It is very likely that this trouble will be remedied by the natural process of silting, as has been the case with

the Pilot Butte canal, and that it will be a matter of only a few years until the loss which now occurs will be greatly reduced.

The stream from which these canals take their water supply gives an abundant flow, and it is thus possible to make these canals more nearly impervious by carrying large heads of silt-laden water. It is yet a question whether the water lost is going to damage the low-lying lands or whether through the peculiar lava formation the water will find its way to the natural water courses without rising to the surface. If the latter is the case, the evil effects of the seepage losses will be confined to decreasing the available supply.

CANALS IN UMATILLA COUNTY.

In Umatilla County a short water supply during a long crop-growing season gives to both land and water a high value and makes the prevention of seepage losses a matter of great importance, while the porous and sandy nature of the soil through which water must be carried makes it difficult.

The Maxwell canal, which heads a few miles above Hermiston, although built several years ago, has been repaired and enlarged and is subject to the heavy losses of a canal newly built. The Irrigon canal, which heads about 3 miles above Umatilla Junction, supplies water to the region around Irrigon. The channel of this canal is built largely in porous, sandy soil, and the loss is very heavy. The measurements of the losses from these two canals, which are given below, do not fairly represent the troubles that are encountered in water conveyance along the Umatilla, but are rather typical of the canals under which the conditions are the most serious. The soils of the Umatilla Basin are not all as porous as those through which the Maxwell and Irrigon canals run, but the problems of conveyance are somewhat similar and the remedies which may be suggested will no doubt be applicable to other ditches in a more or less modified form. But one set of measurements could be made on the Maxwell canal, owing to the fact that the low stage of the river deprived this canal of a supply early in August. On the Irrigon canal it was possible to continue the measurements throughout the season, and as a result the observations on this canal will be found to be quite complete.

MAXWELL CANAL.

The seepage measurements were made on the Maxwell canal on July 20. On this date the discharge at the head gate was 16.3 cubic feet per second, and of this but 3.1 cubic feet per second was being used. The length of the canal in which this loss occurred was 5.23 miles, in which the canal runs through porous, sandy soil, which absorbs the water very rapidly. The canal was divided into four sections for the purpose of determining the losses.

Section No. 1.—This section extended from the head gate to waste gate No. 2, a distance of 1.75 miles. In this length the canal traverses the east bank of the river, and the channel is excavated for the greater part of the way in cement gravel and bowlders. A peculiar characteristic of this material is that when first excavated it is very hard and firm and would seem to be almost impervious, but after the water is turned in the cementing material disintegrates and the channel becomes quite pervious. Aside from the porous nature of the channel as a whole there are no weak points in the line, and while we have no results to substantiate the view, yet it would seem that the loss throughout the section is quite uniform. The width of the water section of this part of the canal averages 14 to 16 feet and the depth at the time of measurement varied from 1 to 2 feet. The grade is uniform throughout, and the velocity low enough so that silting may occur. The channel is new, however, and but little silt has been deposited thus far.

Section No. 2.—This section is comparatively short and includes only a short cement gravel cut just below waste gate No. 2. Its length is approximately 1,200 feet. In this section the greatest loss from the canal has occurred. This material, like that in the upper section, was apparently impervious to water when first opened, but the action of the water has opened the porous spaces and until considerable work had been done the water ran through the bank and down into the river in small rivulets. Prior to the time of making this measurement the company had repaired a portion of this section and by use of straw and manure had stopped most of the leaks in the first 200 feet of the cut. The remaining length, however, had not been treated and it was in this portion that the greatest loss occurred. The canal channel from waste gate No. 2 on is much narrower than the line above it, having been constructed to carry sufficient water for present needs, the idea being to enlarge this section as the demand increases. In this gravel cut the width of the water surface ranges from 7 to 10 feet, and the depth of water from 1.5 to 2 feet. The grade in this section is 5 feet per mile.

Section No. 3.—This section extended from waste gate No. 2 to the point at which lateral No. 1 is taken from the canal, a distance of 1.75 miles. The channel in this section runs through coarse, sandy soil, and in some few places is fairly well silted. The light nature of the soil, however, makes it very easy for washing to occur. Even with a comparatively low velocity the bottom of the channel will remain scoured, and considerable loss occurs through this porous lining. The grade in this section is 1.25 feet per mile, and the velocity of flow varies from 1 foot to 1.6 feet.

Section No. 4.—This section extended from lateral No. 1 to the siphon intake, a distance of 1.5 miles. The channel in this section is

quite similar to that of section No. 3, and so far as outward appearances are concerned would seem about equally as good a water carrier. Toward the lower end of the section the channel is quite well silted, as is the case at several points throughout the line. At the time of measurement the decrease in flow in this section due to loss was noticeable to the eye.

The results of the measurements are given in the following table:

Seepage measurements, Maxwell canal, July 20, 1905.

[In cubic feet per second.]

No. of section.	Section.	Length of section in miles.	Discharge, upper station.	Diversions.	Discharge, lower station.	Loss in section.	Loss per mile.	Percentage of loss per mile.
1	Head gate to waste gate No. 2	1.75	16.3	0	13.1	3.2	1.8	11.2
2	Waste gate No. 2 to end of gravel cut	.23	13.1	0	11.5	1.6	5.2	39.6
3	End of gravel cut to lateral No. 1	1.75	11.5	0	5.9	5.6	3.2	27.8
4	Lateral No. 1 to siphon intake	1.50	5.5	0	3.1	2.4	1.6	29.1
	Total	4.23				12.8		

The necessity of preventing this loss has been realized by the promotors, and during the latter part of the season of 1905 a crew of men were kept at work on the canal. The general method of the treatment consisted in working first those sections of the canal in which the loss had appeared the greatest. In these sections the bottom of the channel was removed to a depth of a foot or more and this space was filled in with a mixture of manure, sand, and gravel and thoroughly puddled with water. Upon this straw blanket the silt which had been removed from the channel was again deposited and also puddled under water by the teams as they traveled back and forth. This was substantially the method used in stopping the loss from the upper end of the gravel cut mentioned in section No. 3. The beneficial effects of this system at that point were very noticeable, for where water had oozed through the bank in small streams prior to the treatment they at once became dry. The success of the treatment of this section led to similar treatment for the other weak sections of the line. The greater part of this work was done after the water was shut out of the canal and it has therefore had no thorough test. Another season, however, it will be possible to determine the effectiveness of this treatment. The great advantage in the use of this method is that it is so inexpensive, the refuse of the farms becoming at once a valuable and serviceable material.

IRRIGON CANAL.

The Irrigon canal heads in the Umatilla River about 2 miles above the junction of the Umatilla with the Columbia. It was designed to irrigate land lying along the Columbia in the extreme northeastern part of Morrow County. The present canal line is a much modified relocation of an old canal which after the new line was constructed was abandoned. In some places it follows the old alignment, but throughout the greater part of its length the channel is of new construction. It has been in use only a few years, and much difficulty has been experienced in making it carry water. During the early part of the season there is water enough and the canal can be kept full at all times; but when the river is low much trouble is encountered in conveying water the full length of the line. The heavy losses not only decrease the water supply but are also doing considerable damage by water-logging low-lying lands. The soil in this section is largely composed of sand which has been blown out of the river. The greater part of the channel is in this soil and, except in portions where a cement gravel formation has been encountered, the entire length of the line is subject to considerable loss. Time after time different remedies have been tried on the canal, but all of them have proved of little benefit. In July of the past season an investigation was begun on this canal to determine seepage losses, and through the courtesy of the officials of the company it was possible to make quite an accurate study of the losses that occur, both as to amount and location, and an opportunity was also afforded to observe certain experimental work which was being carried on by the company to find a means of improving the condition of the canal.

The first series of seepage measurements was undertaken about the middle of July. At that time the water in the river had reached a point where the entire flow of the river was just sufficient to fill the head flume which governs the capacity of the canal. For this series of measurements the canal was divided into five sections which included the entire length of the main line. A second series of measurements was made about a month later and at this time, due to the work which had been done on the canal, it was expected that the loss would be materially decreased and the sections, therefore, were made much shorter and the canal for this series divided into ten sections. A third measurement was made on September 19, about one month later than the second measurement. This last series included only a measurement at the head of the canal and one at the point where the main canal divides and shows only the loss in the main line.

Section No. 1.—This section extended from the head gate to station 50, a distance of a little less than one mile. Of this length 1,800 feet consisted of a flume 4.8 feet wide and capable of carrying water to a

depth of 2 feet. Practically all of the loss from the first section occurs in the earthen section. The condition of this portion of the earth channel was the worst encountered on the entire line. The velocity is such that no silt has been deposited and the surface exposed is of coarse, porous gravel. The cross section is irregular and the banks for the most part are of shifting sand. At several points the banks are light and water trickles through them quite rapidly, forming streams and ponds, which drain back into the river.

Section No. 2.—This section extended from station 50 to station 100, a distance of almost a mile. Through this section the channel is in heavy sand and gravel cuts, is of irregular cross section, and the velocity is such that in portions the sand is kept shifting along the bottom and no silting occurs. There is no visible seepage through the banks in this section, but seepy places are noticeable at various points several hundred feet below the canal.

Section No. 3.—This section extended from station 100 to station 154, a distance of a little over a mile along a rather steep sidehill slope. Much gravel and loose sand is encountered in this section. The cross section is quite uniform and the velocity is such that silting has occurred only at intervals. There is no visible seepage through the bank, but at a distance of 600 to 800 feet away the water comes to the surface and during the earlier part of the season runs toward the river in strong streams.

Section No. 4.—This section extended from station 154 to station 209, a distance of a little more than a mile. It is built on a gentle slope and has a section that is quite uniform. The velocity also is uniform and the greater part of the channel, which originally was in fine sand and gravel, has become well silted and no outward signs of seepage losses are visible.

Section No. 5.—This section extended from station 209 to station 252, a distance of 0.81 mile. In this section the canal was excavated through porous gravel and at the time of construction the excavation was carried below grade to a depth of 8 or 10 inches and this subgrade refilled with fine sand. The cross section of this length is comparatively uniform and is quite well silted. There is no indication of heavy losses from this section.

Section No. 6.—This section extended from station 252 to station 325, a distance of 1.38 miles. It is constructed mostly in sand underneath which is an extensive layer of hardpan at a depth of 4 to 8 feet. The cross section is comparatively uniform and a part of the section is above grade and the water keeps the surface scoured, while the remaining part is below grade and is quite well silted. Heavy leakage occurs in this section. This has done much damage by waterlogging and bringing alkali to the surface on the narrow strip of land lying between the canal line and the river.

Section No. 7.—This section extended from station 325 to station 353, a distance of 0.5 mile in which the channel is of uniform cross section and, being mostly all below grade, the bottom has become well silted. About midway of the section there occurs a layer of hardpan 6 to 8 feet below the surface, which slopes toward the river. Below this point and toward the lower end of the section there is some exposed gravel. In this vicinity indications of heavy seepage are quite noticeable. At a distance of about 400 feet below the canal a pond has been formed which in the earlier part of the season yielded a considerable stream of water which found its way into the river.

Section No. 8.—This section extended from station 353 to station 400, a distance of 0.9 mile. In this section the canal runs through sand cuts in which the cross section is quite uniform. The bottom is fairly well silted and there are no surface indications of seepage along the bank except where a washout occurred near station 396. From station 396 on for the next 200 or 300 feet the loss through the bank in the earlier part of the season was very heavy. Small streams of water could be seen oozing directly from the bank, and trickling down, formed a very considerable stream which gradually seeped away and lost itself in the sand.

Section No. 9.—This section extended from station 400 to station 450, a distance of a little less than a mile. The conditions of the channel in this section are much the same as in section 8. At station 430 the canal leaves the slope of the sidehill and follows a ridge for several hundred feet. In this portion heavy seepage occurs from both banks of the canal.

Section No. 10.—This section extended from station 450 to the junction point of the main line, a distance of 0.38 mile. The channel in this section is much the same as the two just described except that the ground is much more rough and a greater variation exists in the nature of the material passed through. Coarse sand, however, is the predominating material and, due to the low velocity in this length, the bottom and sides are quite well silted.

The results of the three series of measurements are brought together in the following table:

Seepage measurements, Irrigon canal, 1905.

[In cubic feet per second.]

Number of section.	Section.	Length of section in miles.	Discharge upper station.	Diversions.	Discharge lower station.	Loss in section.	Loss per mile	Percentage of loss per mile.
	First series, July 13, 1905.							
1	Headgate to first waste way	1.29	21.6	0	17.6	4.0	3.1	14.4
2	First waste way to center section 14.	2.22	17.6	0	13.0	4.6	2.1	11.7
3	Center line section 14 to east line section 20	2.71	13.0	0	9.4	3.6	1.4	10.4
4	East line section 20 to station 440	2 01	9.4	0	5.7	3.7	1.8	19.4
	Second series, August 8, 1905.							
1	Headgate to station 50	.66	15.6	0	12.6	3.0	4.5	28.8
2	Station 50 to station 100	.95	12.6	0	11.3	1.3	1.4	11.1
3	Station 100 to station 154	1.02	11.3	0.80	8.5	2.0	2.0	17.3
4	Station 154 to station 209	1.04	8.5	0	8.1	.4	.4	4.8
5	Station 209 to station 252	.81	8.1	0	7.8	.3	.4	4.5
6	Station 252 to station 325	1.38	7.8	0	5.8	2.0	1.4	18.8
	Continued Aug. 9, 1905:							
7	Station 325 to station 353	53	7.1	0	6.2	.9	1.7	24.0
8	Station 353 to station 400	.90	6.2	0	5.2	1.0	1.1	17.7
9	Station 400 to station 450	.95	5.2	0	4.2	1.0	1.1	20.2
10	Station 450 to station 470	.38	4.2	0	2.5	1.7	4.4	--------
	Third series, September 19, 1905.							
1	Headgate to station 470	8.9	17.7	1.1	10.3	5.84	.6	3.6

The condition of the canal channel described above in the various sections was true at the date of taking the second series of measurements on August 8 and 9. The season previous much work had been done on the canal channel in order to make it impervious, and in the light of what has been brought about since that time it would seem that much of this work was exerted in the wrong direction. At that time it was thought that by plowing up the bottom of the channel and thoroughly incorporating with the sand such silt as had collected that a more impervious layer would be secured, and to this end a great deal of work was done both in the way of plowing and harrowing the channel and also in the way of packing it by means of a corrugated roller. After this work had been done it seemed as though the channel lost as much water as it had before being treated, and at the beginning of this season it was decided to abandon this practice of stirring up the channel and simply leave the silt to collect as quietly as possible and form a compact layer on top of the sand. No work, therefore, was done in the way of stirring up the channel and during the fore part of the season the silt was allowed to collect without being distributed. The result was that wherever the velocity of the water slowed down a heavy deposit of silt occurred and considerable bodies of silt were formed in the channel in this way. As soon as sufficient silt had collected to form a rooting place for aquatic

plants a growth of moss sprang up, which also aided the deposit of silt. The result of this action was the formation of silt bars wherever the water formed an eddy or wherever the velocity was decreased, and these bars at the time the first series of measurements was made had increased in size to such an extent that they formed a serious obstruction in the channel, backing the water up upon the banks and increasing by a considerable amount the wetted perimeter. This increase in the wetted section, of course, only tended to increase the amount of seepage, and although the canal channel appeared to be full of water, yet it failed to deliver any considerable amount into the distributing laterals at the end of the system. Soon after the first series of measurements was made a campaign was begun to rid the channel of these obstructions. It was thought best not to get rid of this silt entirely, but rather to stir it up and permit it to pass on down the channel and deposit more uniformly in other sections. The bars were harrowed down and the silt was kept thoroughly stirred up in the water and allowed to flow on down the canal. After the worst bars had been reduced a spring-tooth harrow and also a disk harrow were used to further assist in evenly distributing the silt. This treatment, however, seemed to stir up the bottom of the channel much in the same way as did the treatment it received in the previous year. At this time the second series of seepage measurements was made, and the results indicate that the loss was not greatly different from what it had been before the silt bars had been reduced. The wetted perimeter had been lessened, but the wetted surface had been stirred up and made more porous. With a view to producing the same beneficial results without this stirring factor it was suggested that a specially devised implement might be used. This implement consisted, essentially, of a long anchor chain, the ends of which were attached to a beam placed across the running gear of a wagon. This was drawn up and down the canal in such a manner that the loop formed by the chain covered the entire wetted perimeter of the channel and not only stirred up the silt and prevented the moss from growing, but had a rolling effect and thereby compressed the surface of the channel. This device was used continuously for about three weeks, with the result that water was delivered to the foot of the furthermost lateral with a slightly decreased amount entering the head gate—a thing which would have been quite impossible at the time the first series was made.

The result of this treatment is well shown in the résumé of the three series of measurements which is given in the following table:

Resume of three series of measurements of Irrigon canal.

Series.	Date of measurement	Section.	Length in miles.	Discharge at head gate.	Total loss in line.	Loss per mile.	Percentage of loss per mile.
				Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	
1	July 13	Head gate to station 440.	8.33	21.6	15.9	1.90	8.8
2	August 8 and 9	Head gate to division gate (station 470).	8.90	15.6	12.3	1.38	8.8
3	September 19	do	8.90	17.7	5.7	.64	3.6

It will be noticed from this that the loss in July before the channel had been worked at all was about 8.8 per cent per mile, with a head of 21.6 cubic feet at the head gate. After the silt bars and moss had been harrowed down the loss was reduced somewhat, there being 8.8 per cent loss per mile, with a head of 15.6 per cent per cubic foot per second. Between August 8 and September 19, the period during

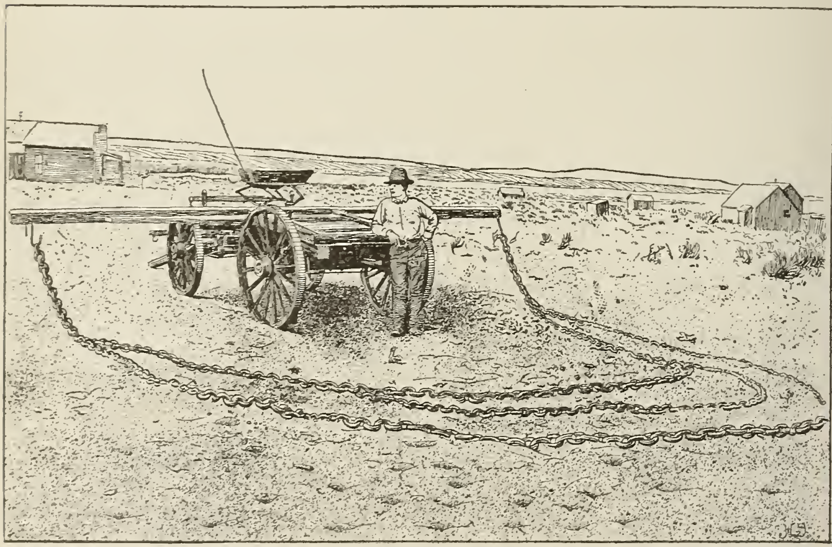

Fig. 2.—Chain puddler.

which the chain puddler was used, this loss was reduced to 3.6 per cent per mile. The chain was at first suggested as a possible means for preventing the excessive growth of moss, but after having been used for this purpose it was found that it not only prevented the growth of moss, but also served to puddle the channel. At various points

along the line, where loss through the bank had been visible, the leakage was stopped, and places below the canal which had been filled with standing water rapidly dried up, showing that the channel had been made quite impervious. This implement as first constructed was made of the hind running gears of a wagon, across which was placed a long beam and at the ends of the beam the ends of the heavy chain were fastened so that when the running gears were drawn forward the chain would drag in a long loop and have a rolling effect which not only tore out the roots of the moss but also rolled and puddled the surface. Encouraged by the beneficial results obtained with this crude implement, a longer and heavier chain was secured and the implement shown in figure 2 was constructed. This soon developed a weakness in one respect. The long loop of the chain tended to roll the silt from the sides of the channel toward the center and formed a cross section somewhat similar to figure 3. The implement in its latest form has the chain fastened or hung from the supporting frame in a manner indicated by figure 4, and the dragging of the earth toward the center of the channel has been almost entirely eliminated.

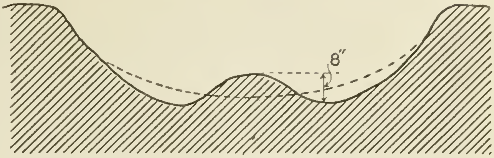

Fig. 3.—Cross section of channel after use of chain puddler.

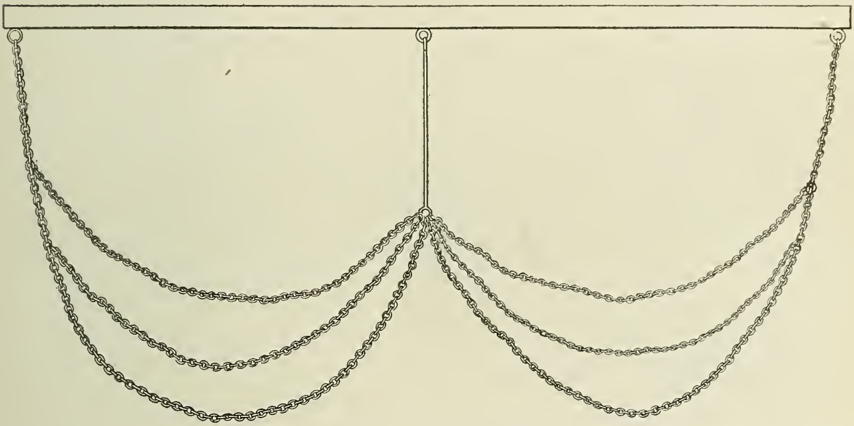

Fig. 4.—Modification of chain puddler.

The experiment thus far indicates that such an implement is going to prove of much value in puddling light, sandy soils. Such an implement is easy of operation on the smaller channels and can be used at moderate expense.

CONCLUSIONS.

Perhaps the most urgent need in the irrigated sections of Oregon is for better methods of preparing land for irrigation and of applying water to crops. Improvements in present practice are suggested in the preceding pages.

The measurements of losses of water from canals, reported in the preceding pages, show that this matter deserves a great deal of attention. The most common cause for excessive losses seems to be the giving of too heavy grades to canal lines. This prevents the settling of the silt, which, if deposited in the canals, would go far toward stopping seepage losses. The observations show, however, that if the silt accumulates in bars sufficiently to check the flow of the water this holding up of the water may cause losses as great as those caused by erosion of the channel. This whole investigation points to the necessity of having canals carefully proportioned to the work to be done. The chain puddler described on page 27 seems to be the most effective means yet discovered of puddling the silt in canals and preventing the growth of aquatic plants.

Losses of water from canals and drainage from irrigated land have brought about the swamping of considerable areas and the accumulation of alkali in some places. Unless losses are stopped this damage will continue. The damaged lands must be reclaimed by drainage. In many sections development has not yet reached the stage where such drainage will be profitable, but in other places it might well be undertaken.

Winter irrigation has been a marked success in Butter Creek Valley, but this success seems to be largely due to the peculiar conditions of the subsoil. The experience in Butter Creek Valley, however, has led to the belief that other large areas in eastern Oregon can be reclaimed in the same way. Success is, however, doubtful except in sections where there is an impervious subsoil which will prevent the water applied from draining away.

Recommended for publication.
A. C. True, *Director.*

Publication authorized.
James Wilson,
Secretary of Agriculture.

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